DSN Research and Technology Support

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Major activities in support of the Deep Space Network (DSN) research and technology program are presented for the last 6 mo. Work was performed at both the Venus Deep Space Station and the Microwave Test Facility. Progress and performance summaries are given in the following areas: radiometric observations (20–25 GHz); pulsars and planetary radar; 26-m antenna upgrade; precision antenna gain measurements; weak source observations; and radio star observations (Cygnus A); the Mars Deep Space Station transmitter rework and testing; transmitter development; 100-kW clock synchronization (X-band); switched carrier experiment; 400-kW harmonic filter; dual 20-kW transmitters; horizontal mill installation; clock synchronization transmissions; and acceptance testing of DSIF klystrons.

The Development Support Group, was recently or is currently engaged in the following activities at DSS 13 and the Microwave Test Facility at GDSCC:

I. DSS 13 Activities

A. In Support of JPL Section 325

Section 325 personnel have equipped the 9-m antenna with a multichannel radiometer operating between 20 and 25 GHz. On a noninterference basis, they have been making radiometric observations, principally of Venus, but also of various radió sources and interstellar and intergalactic spaces, for several years. They time share the antenna, antenna drive computer, and servo system with the Development Support Group of Section 335 on a noninterference basis.

B. In Support of Section 331

1. Pulsars. In a continuing program, ongoing now for more than two years, twenty of the approximately fifty known pulsars are observed at DSS 13 at 2388 MHz. The averaged pulse power density spectrum of each pulsar, the pulse spacing (to eight significant figures) and pulse arrival time at the DSS 13 26-m antenna comprise the data extracted from these observations. With timing controlled by a cesium frequency standard, the receiver output is sampled at a rate of 5,000 samples per pulse period (except for pulsar 0833, which is sampled at a rate of 5,000 samples per three pulse periods) and data from successive pulses are integrated to improve the signal-to-noise ratio. (Table 1 tabulates the pulsars which are regularly observed.)

2. Planetary radar. In another continuing program, from the inception of DSS 13, various planets are illuminated with a CW or PM signal and the reflected signal is received. The planet Venus is the target most observed. Mars and Mercury have also been successfully observed, using both total spectrum and ranging techniques. (High-precision ranging of Mars was performed prior to *Mariner* 1969 encounter to provide the project with an improved ephemeris for use during the encounter sequence. Range to the surface of Mars was measured to a resolution of better than 1500 m.)

Using bistatic techniques (transmitting from DSS 13 and receiving at DSS 14), the range to Venus and Mercury is currently being measured on a weekly basis. The range resolution to Venus is better than 1500 m, while the resolution to Mercury is somewhat worse. Various transmitter powers have been used over the years in which this project has been continuing, but currently we use 400 kW at DSS 13 and will have 400 kW at DSS 14 later this year. (The DSS 14 transmitter has been removed and is undergoing renovation at DSS 13.)

C. In Support of Section 332

1. 26-Meter antenna upgrade. During a three-month period commencing in January 1971, extensive structural work was done on the 26-m antenna. It had been discovered during previous studies that the moment arms of the two elevation ball screws were not identical, and this differential movement caused localized distortion of the attaching girder, resulting in a raised area in the dish surface. By mounting the elevation bearing of one of the ball screws on an eccentric (a 6.35-mm [¼ in.] eccentric was used after a 3.2-mm [⅛ in.] one was discovered to not have enough range) and adjusting it, the localized dish surface distortion was minimized.

Three-inch angles were welded into a truss structure to increase the stiffness in the outer ring of the antenna backup structure and were installed behind the outer row of surface panels. Measurements of surface deformation due to gravity were taken before and after installation of the stiffeners, but data reduction had not yet been accomplished. After the changes to the elevation bearing and the installation of the stiffeners, the surface deviation from the desired parabola was measured and panel adjustment accomplished for a best-fit parabola. Unfortunately, weather conditions prevented complete measurements from being made within the scheduled time and the data set is incomplete.

D. In Support of Section 333

1. Precision antenna gain measurement. Using the ALSEP left on the Moon by *Apollo 12* as a collimation signal source, observations are being made with the 26-m antenna and a gain standard horn (gain measurement traceable to NBS) in order to measure the ratio of power received by the two antennas. Observations made to date indicate that overall stability is worse than anticipated, and digital processing techniques will be necessary to data collection, rather than the simpler analog chart recordings which had been planned. A program has been written[1] for this effort which samples the receiver AGC voltage once per second, and records the output level, along with a time tag and a start-run stop-run signal, onto magnetic tape. The program also provides simultaneous printout of sample values while recording. Run-to-run averaging, plotting of results on an X-Y plotter and punching averaged runs onto paper tape while recording on magnetic tape is also provided. Operational utilization of this data collection approach will commence on April 15, 1971.

2. Weak source observation. To improve the minimum observable change in total system temperature while observing weak radio sources, the effects of gain changes in the receiving system are removed by time sharing the system between a signal from the radio source and a signal from the radio source plus a calibrated noise source (noise diode). Knowing the noise power output to be expected from the calibrated noise source, the effects of gain changes subsequent to the injection point can be computed and corrected. The antenna pointing, keying of the noise diode, sampling of the receiver output and computation are done by the SDS-930 computer. Work is under way to provide an addition to the program which will "scan" the antenna back and forth across the source in a "raster" scan similar to the manner in which the electron beam in a television set scans the face of the CRT. Current schedules provide for weak source observation for 24 h each month.

3. Radio star observations (Cygnus A). To provide data on a radio source which can be used by all the

[1]By Robert Gosline.

DSIF stations, observations of Cygnus A are made and the increase in system temperature resulting from this source is measured. These data, along with the gain ratio data from the ALSEP observations, can then be used by other DSIF stations to make antenna gain measurements by measuring the increase in their antenna system temperature when observing Cygnus A. For the Venus station 26-m antenna, the measured increase in system temperature from Cygnus A clusters around 100°K, but further measurements will narrow the error bars on this data.

E. In Support of Section 335

1. DSS 14 transmitter rework and testing. On March 15, 1971, the two 400-kW transmitters were removed from DSS 14 and brought to DSS 13 for rework and acceptance testing in preparation for official transfer to an operational status. Reinstallation of the DSN 400-kW transmitter is scheduled to take place not later than July 1, 1971.

2. Transmitter development. As part of the continuing program of development carried out by Section 335, generation of dual uplink carriers is being experimented with at DSS 13 by use of two separate exciters whose outputs are combined and used as input power to the 400-kW klystron. To reduce intermodulation distortion, the power levels are reduced to a nominal 40 kW per carrier. Measurements are made of the resulting sideband amplitudes, stability, frequency pulling, etc.

Transmitter automation approaches are being tested at DSS 13. The first step is installation of a programmable high-voltage control and monitoring circuit in which the desired voltage level is loaded into registers and the device then brings up high voltage and maintains it at the desired point. Installation of a computer for monitoring of several hundred test points, as well as control of the system, is planned for the near future.

3. 100-kW Clock synchronization (X-band). By installation of a larger capacity heat exchanger and cooling water circulation system, modification of the high-voltage power supply for higher voltage, and procurement of a new transmitter klystron and feed system, the power output of the clock synchronization transmitter will be increased to 100 kW at 7149.9 MHz as compared to 25 kW at 8450.1 MHz now existing.

Strengthening of the antenna-mounted electronics house has been completed, the installation of a stronger floor is one half completed, a platform and associated hoist has been installed for raising and installing the transmitter klystron, and additional power capacity for operation of pumps and fans has been installed on the antenna.

An auxiliary power supply has been installed with which to maintain operation while connection and initial testing of the final high-voltage supply is underway. The solid-state rectifier, high-voltage transformer, and filter capacitor and choke for the final high-voltage power supply have been installed in the power supply building (G-61). Work continues on a noninterference basis with operation of the clock synchronization transmissions.

F. In Support of Section 337

1. Clock synchronization transmissions. Using the 9-m antenna, equipped with a 25-kW transmitter operating at 8450.1 MHz, pseudonoise-coded, phase-modulated signals are broadcast to DSSs 14, 41, 42, 51, and 62 using the moon as a reflector. These transmissions, whose frequency and timing are controlled by a rubidium and cesium frequency standard, allow the receiving station to compare time within plus/minus 10 μs with the master clock at DSS 13. The DSS 13 clock is adjusted as necessary to maintain a time within ± 3 μs of NBS clock 8. (Generally the adjustments are made just prior to each transmission, and resolution of 0.1 μs with reference to the timing pulse from the Standard Laboratories at DSS 12 is achieved.) Operation on this system, which has been out of service for 15 days for modification, will resume on April 15, 1971 with an increase in transmitter power to 100 kW planned for October 1, 1971, at which time a frequency change to 7149.9 MHz will take place.

II. Microwave Test Facility (MTF) Activities

A. In Support of Section 335

1. Switched carrier. In general support of the requirement for generation of two simultaneous uplink carriers, an investigation[2] into timesharing a single transmitter klystron between two exciters, has been under way for approximately nine months. Technical feasibility has been demonstrated, but no spacecraft experiments were conducted. A more detailed look at this investigation is given in "Switched Carrier Experiments" by Richard Kolbly, which appears on p. 133

2. 400-kW Harmonic filter. The installation of the DSN 400-kW transmitter at DSS 14, operating at the

[2]Suggested by Mahlon Easterling.

spacecraft uplink frequency (2115 MHz) rather than the research frequency (2388 MHz) used at DSS 13, necessitated suppression of harmonic radiation lest it interfere with the spacecraft downlink reception. Procurement of a harmonic filter, in WR-430 waveguide, to operate at this power level, proved somewhat difficult and problems were experienced with noise bursts.

Examination of a partially disassembled filter indicated that it contained dirt, copper shavings (machining residue), general debris and some unknown chemical deposits or growth. After consultation with the manufacturer to determine what adhesives were employed in construction of the device, cleaning was undertaken. While disassembled for cleaning, modifications to the water cooling circuits were made to improve cooling and decrease leak problems. Due to the segmented construction of the harmonic absorbers, cleaning was difficult, but by use of special solvents and careful manual scrubbing, the filter was completely cleaned, the water circuits modified, and the filter repainted white.

3. ***Dual 20-kW transmitter.*** To improve test capability, and also to have the capability for conventional generation of dual carriers, a 20-kW transmitter (surplus from the STADAN project) was obtained and installed. This second transmitter is now operational and the Microwave Test Facility can simultaneously generate two 20-kW carriers at appropriate uplink frequencies.

4. ***Horizontal mill.*** For increased efficiency in fabricating waveguide sections and milling of waveguide flanges, a horizontal mill (surplus from Edwards Air Force Base) was obtained and installed. The machine has been connected to power, thoroughly cleaned, motor operation verified, and is ready for operation as soon as cutting heads are installed.

B. In Support of Section 337

1. ***Acceptance testing of DSIF klystrons.*** To avoid a testing operation in an operational DSIF station, incoming transmitter klystrons are brought to the MTF for formal acceptance testing. The klystron is tuned, bandwidth and drive requirements ascertained, compliance with power output specifications verified, and nominal values of all parameters, especially magnet current, obtained. These data are recorded onto an acceptance test data sheet which is then packed with the klystron when it leaves the facility for its station destination. Additionally, klystrons removed from DSIF stations are tested at MTF to ensure that the klystron is, in fact, defective, prior to shipment to the vendor for rebuild or repair. During the year ending April 1, 1971, twenty-four DSIF klystrons have been tested at MTF, either for incoming acceptance tests or verification of reported failure.

Table 1. Pulsars currently being observed at DSS 13 at 2388 MHz

Pulsar	Sidereal hour angle	Declination
0031	351.834	352.497
0329	307.314	54.482
0525	278.253	21.986
0628	262.577	331.438
0823	233.728	26.722
0833	231.415	314.929
0950	212.098	8.070
1133	186.368	16.011
1237	170.423	25.045
1642	109.164	356.750
1749	92.221	331.891
1818	85.169	355.591
1911	71.915	355.250
1929	67.291	10.926
1933	66.384	16.210
2016	55.788	28.571
2021	54.606	51.765
2045	48.267	343.618
2111	41.882	46.684
2218	25.209	47.769